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AN ANALYSIS OF THE REQUIREMENT FOR AN AUXILLIARY POWER UNIT ON --ETC(U)

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**ANALYSIS OF THE REQUIREMENT
FOR AN
AUXILIARY POWER UNIT
ON**



MAIN BATTLE TANKS



VOLUME I - MAIN REPORT

**HEADQUARTERS
US ARMY ARMOR CENTER
Ft. Knox, Ky.**



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UNITED STATES ARMY
ARMOR CENTER

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FOR AN
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DISCLAIMER

The findings and conclusions in this report are not to be construed as an official Department of the Army position.

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ACKNOWLEDGEMENT

This report is an "in-house" US Army Armor Center effort.

This report has been approved by the Commanding General, US Army Armor Center.

The conclusions and recommendations in the report are those of the US Army Armor Center.

The report was prepared by Studies Division, Directorate of Combat Developments, US Army Armor Center.

The following organizations provided valuable assistance and support:
US Army Tank Automotive Research and Development Command, Project Manager XM-1 Tank, Project Manager M-60 Tanks, and DOD Project Manager for Mobile Electric Power.

ABSTRACT

↙ This report presents the US Army Armor Center rationale and justification for adding auxiliary power units to current and future main battle tanks. The findings and recommendations are based upon data gathered in an extensive worldwide field survey of armor and armored cavalry units. ↘

SUMMARY

1. INTRODUCTION. The subject of auxiliary power units (APU) on main battle tanks has been a topic of frequent discussion. The US Army has not had an APU on tanks since the introduction of diesel engines on the M48A3 and M60 series tanks. No APU is planned for the XM-1 tank. Increasing electrical demands on main battle tanks and the importance of fuel conservation were the primary factors contributing to the need for this analysis.

2. PURPOSE. This analysis was conducted by the USAARMC to determine if there is a requirement for an APU on main battle tanks.

3. OBJECTIVES.

- a. Determine if there is a requirement for an APU on main battle tanks.
- b. If there is a requirement then:
 - (1) Identify advantages and disadvantages.
 - (2) Identify space tradeoffs.
 - (3) Determine if armor units have a "cold weather" starting problem.
 - (4) Determine critical electrical components that must be powered during "silent watch."
 - (5) Determine percentage of time an APU could replace main engine running time.
 - (6) Determine the "peacetime profile" for tanks and armor units.
- c. Recommend parameters and employment criteria for an APU requirement.

4. METHODOLOGY. (See Section IV for details.) The Armor Center in conjunction with Project Managers for XM-1 and M60 tanks elected to use a four phase approach.

Phase I - Determine if there is a requirement for APU's on tanks. This report completes Phase I. NOTE: Subsequent phases are dependent upon a positive requirement in Phase I.

Phase II - Design system specifications for an APU.

Phase III - Evaluate potential APU's.

Phase IV - Perform necessary materiel acquisition procedures to procure an APU.

5. FINDINGS. (See Section V for details.)

a. There is a requirement for an APU on main battle tanks. (More than 90 percent of the armor personnel surveyed indicated a requirement.)

b. The single most important advantage an APU would provide is a "Silent Watch" capability.

c. Fuel space should be traded off for an APU.

d. Fifty percent of armor units worldwide have a "cold weather" starting problem.

e. An APU could replace about 38 percent of the current main engine idle time.

6. CONCLUSIONS. (See Section VI for details.)

a. The overriding tactical advantage for an APU is to have a "Silent Watch" capability without running the tank main engine.

b. An APU would virtually solve the "cold weather" starting problem on M60 series tanks.

c. An APU would provide significant fuel savings on the XM-1 tank.

7. RECOMMENDATIONS.

a. That USAARMC in conjunction with: TARADCOM, Project Managers for M60 and XM-1 Tanks, and Project Manager DOD Mobile Electric Power - expedite development and procurement of an APU.

b. That, if possible, a common APU for M60 and XM-1 tanks be procured.

c. That DOD PM Mobile Electric Power in conjunction with TRADOC proponents, consider the requirement for an APU on other combat vehicles.

CONTENTS

	PAGE
TITLE PAGE	i
NOTICES	ii
ACKNOWLEDGMENT	iii
ABSTRACT	iv
SUMMARY	v
MAIN REPORT - VOLUME I	
SECTION I - INTRODUCTION	I-1
SECTION II - BACKGROUND	II-1
SECTION III - APPROACH TO SOLVING THE PROBLEM	III-1
SECTION IV - METHODOLOGY	IV-1
SECTION V - RESULTS	V-1
SECTION VI - CONCLUSIONS	VI-1
SECTION VII - RECOMMENDATIONS	VII-1
APPENDIX A - INDIVIDUAL SURVEY FORM	A-1
APPENDIX B - UNIT QUESTIONNAIRE	B-1
APPENDIX C - SURVEY RESULTS	C-1
APPENDIX D - DISTRIBUTION	D-1
COMPUTER PROGRAM AND SURVEY RESULTS - VOLUME II	

SECTION I

INTRODUCTION

I-1. PURPOSE. This analysis was conducted by the USAARMC to determine if there is a requirement for Auxiliary Power Unit (APU) on main battle tanks (MBT).

I-2. OBJECTIVES.

- a. Determine if there is a requirement for an APU.
- b. If there is a requirement then:
 - (1) Identify advantages and disadvantages.
 - (2) Identify benefits an APU would provide.
 - (3) Identify space tradeoffs necessary to install an APU.
 - (4) Determine if tanks and armor units have a "cold weather" starting problem.
 - (5) Determine critical electrical components on a tank that must be operational during "silent watch."
 - (6) Determine percentage of time an APU could replace main engine running time.
 - (7) Determine the "peacetime profile" for tanks and armor units.
- c. Recommend parameters and employment criteria for an APU requirement.

I-3. KEY DEFINITIONS. The following definitions apply to this report:

- a. Auxiliary Power Unit (APU) - A small engine-generator capable of producing DC electrical power to charge/recharge the batteries of a tank.
- b. Cold Weather Starting - Starting of the tank main engine at temperatures below freezing (32°F).
- c. Silent Watch - The tank is in a static position, including periods of limited visibility or darkness. The main engine is off. Electrical and hydraulic power is on to operate all of the communications, target acquisition, fire control, and weapon systems. Noise, light discipline, and local security are of paramount consideration so that the vehicle/crew position is not given away.

d. IR, Thermal Signature - The active infrared signature emitted from IR sources such as searchlights and driving lights and the thermal heat energy emitted from any warm piece of equipment such as engine, tank, etc.

e. "Slave" or "jump" starting - Starting of a tank by means of a cable to another vehicle which is operating in order to produce sufficient electrical power to start the "dead" tank.

f. Environmental systems - Includes the personnel heater, exhaust blower, and gas particulate unit system on tanks.

g. Fire control systems - Those systems necessary to fire the main gun and coaxial machinegun of a tank, i.e., firing circuits, computer, rangefinder, ballistic drive, turret power, stabilization system, and sighting instruments.

h. Visual devices - All active and passive, day and night sights, periscopes, telescopes, and rangefinders found in tanks.

SECTION II

BACKGROUND

II-1. HISTORICAL USES OF APU's. The United States Army has used an auxiliary generating unit or APU on all main battle tanks starting with the M3 "Grant" tank in 1940 through the M48A2C produced through 1960. Main battle tanks employing an APU included: the M3, M4, M26, M41, M46, M47, M48 and M103 series tanks. Various other armored vehicles which have employed an APU include all armored recovery vehicles produced from the M32 through the M88A1 series; the M10, M18, and M36 tank destroyers; various armored self-propelled artillery to include the M44, M52, M53, and M55 series and self-propelled antiaircraft weapons to include the M19 series. The M577, Command Post Carrier, has a 4.2 KW gasoline powered APU.

II-2. PRIMARY USES OF THE APU. Initial uses of the APU on early armored vehicles was to charge the batteries when other on-vehicle systems exceeded the electrical output of the normal engine generator and to provide heat to the engine compartment to assist in cold weather starting of the engine (cold weather was defined as below 50°F at that time). Subsequent uses of the APU included main engine fuel conservation, heat for the crew compartment, main engine signature reduction (noise and smoke), and normal engine start procedures. (The APU would be started with the batteries and then the main engine was started.) Tank main engines for the M3 through M48A2C series tanks were gasoline engines. As improvements and sophistication increased in tanks in the area of armament, firepower, armor, and mobility, a corresponding increase in engine size and horsepower was required; the larger and more powerful the engine, the more fuel it would consume. To gain maximum mission time and range for tanks, APU's were used to conserve main engine fuel and recharge batteries which were being drained by sophisticated sighting and fire control. Rather than run the main engine to provide this electrical power, an APU provided the same electrical output at reduced fuel consumption.

II-3. PROBLEMS WITH EARLY APU'S.

a. The earliest two cycle APU's required a separate fuel tank with gasoline and oil mixed in the proper proportions. Follow-on APU's were small multi-cylinder 4-cycle engines which used the standard gasoline fuel from the main fuel tanks.

b. Maintenance on the APU's was time consuming and difficult. Maintenance personnel received very little training on the APU and required knowledge of small gasoline engine and generator repair...a skill not generally taught engine mechanics. Oil levels on the small APU engines were critical and required frequent checking by the tank crew. Good human factors engineering was not incorporated into the APU/tank system and resulted in difficulty in maintaining APU's. Procurement of APU's from several manufacturers resulted in non-standard repair parts, hence logistics support of the APU was difficult.

c. Even with the above mentioned deficiencies the APU's received wide spread troop acceptance for the reasons stated in paragraph II-2 above. "Little Joe" as the APU was nicknamed made the tank systems of those days effective cold weather, all environment fighting systems.

II-4. REASONS FOR DISCONTINUING APU'S ON TANKS.

a. With the introduction of diesel engines in US tanks, starting with the M60 and M48A3, the APU was discontinued. Diesel tank engines could be run at considerably lower fuel consumption rates than the previous gasoline tank engines and in many cases lower rates than the APU. Thus on a fuel cost effectiveness basis the main engine could be run as cheaply as an APU.

b. Diesel engines could effectively start at much lower temperatures than gasoline tank engines, thus the APU wasn't needed for cold weather starting.

c. Small diesel engine technology in the US was nonexistent in the sizes required for an APU. Basically this statement is still true today. Foreign technology, specifically Japanese and European, is far ahead of the US in small efficient diesel engines. For example, the APU on the M88A1 diesel recovery vehicle had to be procured from Canada because none were available in the US.

d. The Army users of an armored vehicle, justifiably would not accept the logistic burdens associated with maintaining and supplying a gasoline APU-diesel main engine combination on tanks.

II-5. FOLLOW-ON TANK DEVELOPMENT (MBT-70, XM803, AND XM-1).

a. MBT-70/XM803. At various times in the MBT-70 and XM803 tank programs a requirement for an APU existed. The APU was required for battery charging, cold weather starting, noise reduction, supplying hydraulic power, for use during silent watch operations, for emergency use when the main engine generator was inoperable, and as part of the winterization kit. The electrical requirements for the auto loader and

the Shillelagh missile system also supported an APU. Termination of these tank programs ended the consideration of APU's.

b. XM-1. The Main Battle Tank Study Group (1971) addressed whether the XM-1 should have an APU. For many of the same reasons stated in paragraph II-3, it was decided not to incorporate an APU materiel need requirement for the XM-1. The Tank Special Study Group in 1975 addressed an APU as a side issue and determined that there was no inherent need for an APU because of weight, space, and operational capability. However, the Tank Special Study Group did recommend that an APU be considered as part of a separate arctic kit on the XM-1.

c. Conclusions. All M60 series follow-on development efforts considered the adoption of an APU, but one was never recommended. It appears the following factors contributed to this situation.

(1) Cost Ceilings - When considering advanced (and costly) fire control, propulsion and suspension requirements, there was not enough money for an APU. Further, then and now, the priority for an APU is not as critical as the major components of an advanced tank, such as the XM-1.

(2) Lack of US Technology - There has been and appears to be a lack of US technology to produce a small diesel engine suitable for use as an APU.

(3) Cold-Weather Starting - The adoption of diesel main engines was a quantum improvement in cold weather starting. It should be noted however, even today, contrary to preconceived ideas, this problem still exists. In sum, cold weather starting has been ignored.

(4) Energy Conservation - Until recently this subject has not received serious attention. There has been no real incentive for fuel conservation measures.

II-6. RECENT ACTIONS RELATING TO AN APU ON TANKS. There has been considerable renewed interest in putting an APU back on tanks. Primary reasons for this interest are:

a. Cost and amount of fuel consumed by tanks. The fuel crisis of 1973 highlighted US dependence upon foreign sources and increased costs for fuel. The introduction of higher horsepower gas turbine engines has resulted in higher fuel consumption rates. If the use of an APU can reduce overall fuel consumption, then mission time can be increased. Additionally, less running time on the main engine will reduce maintenance costs.

b. Increased tank electrical demand. The M60 tank originally used a 300 amp generator. The M60A1 RISE modification uses a 600 amp generator. New systems such as the tank thermal sight place a considerable demand on batteries and generators. The trend is definitely toward a greater electrical consumption requirement.

c. Formal and informal unit feedback indicates there is a cold weather starting problem.

d. The Wagner Task Force at DA in September 1977, in reviewing the Tank Force Management Group's recommendations; recommended that an APU be considered for main battle tanks.

e. Infrared (IR) signature reduction has received considerable attention. An APU would present a much smaller IR signature than that of a tank main engine.

SECTION III

APPROACH TO SOLVING THE PROBLEM

III-1. GENERAL. The Armor Center in conjunction with the Project Managers for XM-1 and the M60 Main Battle tanks elected to use a four phase approach to solving the problem. The progression from phase I through IV is totally dependent upon successful completion of each previous phase. Phase I involved an analysis of the requirement, i.e., is there a need for an auxiliary power unit (APU) on main battle tanks? Phase II involves designing the system specifications necessary to accomplish the requirement. Phase III involves an evaluation of potential systems to perform the APU function. Phase IV involves selecting the desired system and performing those materiel acquisition procedures necessary to procure the system.

III-2. PHASE I - REQUIREMENT ANALYSIS.

a. General. The purpose of this phase was to determine, if there was a need or requirement for an auxiliary power unit on tanks. Initial reviews of field tests, studies, COEA's, historical vehicle records and discussions with subject matter experts at the Armor Center revealed there was no data available to support or refute a requirement for an APU. Further, subject matter experts were divided on their opinions concerning the need for an APU. Faced with this void in data relating to APU's, the study team examined alternative methods to gain APU related data. The solution to the data void was to use subjective analysis as a means to determine if there is a need for an APU.

b. Methodology. The methodology for the subjective analysis involved a three-step approach. Step 1 involved a personal field survey of 50 percent of armor and cavalry units worldwide. Since there are approximately 70 tank battalions and armored cavalry squadrons worldwide, a 50 percent sample would insure that all geographic, environmental, and equipment differences would be taken into account by the survey. Within the surveyed units, personnel were surveyed based on grade and duty position. The distribution of personnel for individual survey ranged in grade from LTC - battalion commander to SSG - tank commander. Furthermore, the sampling distribution was such that the results would insure consensus at a high confidence level. The sampling distribution is shown at Figure 1. A sample of the individual survey form is at Appendix A. In addition to the individual survey forms, the unit staff was required to fill out a unit questionnaire. This questionnaire was used to provide consumption, expenditure, and historical unit data for comparison with individual data obtained from the individual survey forms. A sample of the unit questionnaire is at Appendix B.

(1) Step 2 of the methodology involved an evaluation of the field survey data. Objectives of this evaluation were to determine user consensus to develop actual peacetime operational profiles, to develop potential war time operational profiles, and to obtain user tradeoff (space, location, resources) recommendations in the event a need was realized for an APU. The primary tool for evaluating the field surveys was a USAARMC developed data reduction analysis computer program which is described in Section IV-3 of this report. The completion data reduction program and survey results are contained in Volume II.

GRADE	TANK BN		ACS, ACR		ACS, DIV	
	# SURVEYED	# IN UNIT	# SURVEYED	# IN UNIT	# SURVEYED	# IN UNIT
LTC ¹	1	1	1	1	1	1
MAJ ¹	1	2	1	2	1	2
CPT ¹	4	9	4	9	4	8
LT ¹	8	18	9	19	8	15
WO ²	1	1	1	1	1	1
E7 ³	5	10	7	14	7	12
E6 ³	17	37	17	30	10	18
TOTAL	37	78	37	76	32	52

Figure 1. Personnel surveyed by type unit

NOTES: 1 - Only Commissioned Officers in MOS 12A.

2 - Maintenance Officers - MOS 67A.

3 - Only MOS 19E (previously 11E).

(2) Step 3 of the methodology involves a relatively simple tradeoff analysis to determine the impact/contribution of an APU in terms of reduced vehicle signature, fuel consumption, maintenance, and various other factors.

NOTE: Phase II, III, and IV are dependent upon a positive response to Phase I objectives, i.e. There is a valid need for an APU. If there is not a positive response to Phase I, then Phases II, III and IV would not be necessary and would not be conducted.

III-2. PHASE II - SYSTEM SPECIFICATIONS. The purpose of Phase II is to define the parameters and minimum and maximum characteristics for APU systems for both XM1 and M60 series tanks. The methodology involves an investigation of the power requirements, fuel consumption and capacity, signature constraints, weight and volume constraints, and RAM-D characteristics; an application of the Phase I tradeoff criteria; and a refinement of the desired specifications and requirements.

III-3. PHASE III - CANDIDATE EVALUATION. The purpose of Phase III is to evaluate candidate and potential candidate systems that meet the specifications developed during Phase II. Conduct of Phase III would involve testing of actual hardware, evaluating other potential candidates, and producing R&D and procurement cost estimates.

III-4. PHASE IV - SELECT SYSTEM. The purpose of Phase IV would be to select the best system or systems for both XM-1 and M60 series tanks. Conduct of Phase IV would involve simple COEA or cost benefit analysis using data derived from the previous phases and the writing and staffing of an appropriate requirements document.

SECTION IV
METHODOLOGY

IV-1. ASSUMPTIONS. The following assumptions were made:

- a. The APU may have a potential use for the XM-1 and M60 series tanks.
- b. The APU would not be applied to the M60A2, M551, or M48A5.
Rationale for this assumption was that those systems are low density systems with a limited remaining life cycle.
- c. That if an APU is required, the system would probably be common to both the XM-1 and M60 series.
- d. The APU would burn the same fuel as the tank main engine.
- e. The personnel and units sampled in the survey were representative of all Armor and Cavalry units. That is, the units surveyed had no unique requirements or environmental conditions which would not be encountered in other units.

IV-2. CONDUCT OF THE SURVEY. After coordination with the MACOM's and divisional units, a USAARMC team administered the individual questionnaires to the selected personnel of each battalion and squadron. Units which participated in the survey are shown in Figure 2.

CONUS:

Ft Knox, KY
4th Bn, 37th Armor
5th Bn, 33d Armor
3d Bn, 1st Tng Bde (AITA)

Ft Bliss, TX
2d Sqdn, 3d ACR
3d Sqdn, 3d ACR

Ft Carson, CO
1st Bn, 77th Armor, 4th Inf Div (Mech)
4th Bn, 40 Armor, 4th Inf Div (Mech)
1st Sqdn, 10 Cav, 4th Inf Div (Mech)

Ft Riley, KS
1st Bn, 63rd Armor, 1st Inf Div (Mech)
2d Bn, 63rd Armor, 1st Inf Div (Mech)
1st Sqdn, 4th Cav, 1st Inf Div (Mech)

Ft Polk, LA
3d Bn, 77th Armor, 5th Inf Div (Mech)
1st Bn, 40th Armor, 5th Inf Div (Mech)
4th Sqdn, 12 Cav, 5th Inf Div (Mech)

Ft Lewis, WA
2d Bn, 77th Armor, 9th Inf Div

USAREUR:

8th Mech Inf:
2d Bn, 68th Armor
3d Bn, 68th Armor
1st Bn, 70th Armor
(4th Mech Div)

11th ACR
3d Sqdn, 11th ACR

3d Armored Div
2d Bn, 33d Armor
3d Sqdn, 12th Cav

2d ACR
2d Sqdn, 2d ACR
3d Sqdn, 2d ACR

1st Armored Div
1st Bn, 13th Armor
1st Bn, 35th Armor
2d Bn, 81st Armor

3d Mech Inf
1st Bn, 64th Armor
2d Bn, 64th Armor
3d Bn, 64th Armor

Figure 2. Units participating in survey.

IV-3. DATA REDUCTION.

a. Description of the Data Base. In the course of conducting the survey to determine whether there is or is not a need for auxiliary power units on tanks, 740 soldiers from 29 units were polled. Each of these 740 individuals provided 90 pieces of data from the individual questionnaires (Appendix A) plus unit questionnaires (Appendix B) containing 40 pieces of data were filled out by most of the battalion/squadron staffs. Thus, the data base collected for this study contains 67,560 pieces of data. Without some logical approach to data reduction, this mass of data would be useless in the decision making process.

b. Method of Data Reduction. Consideration was given to the use of prepackaged statistical analysis routines, such as the Statistical Package for the Social Sciences (SPSS) and the BIOMED package for data reduction. After examining the documentation of the existing routines, the nature and format of the input data available, and the required output of the data reduction, it was determined that the existing statistical packages would not provide all of the answers needed and that an excessively large number of runs would be required in order to provide the portion of the output that they could produce. Consequently, the approach diagrammed in Figure 3 was selected for data reduction in this study.

(1) First, all of the data collected from the survey questionnaires was key punched and manually checked for errors. Two separate card decks resulted from this step. One, 72 cards long, contains all unit data; e.g., number and types of tanks in the unit, fuel consumption data for the unit, number of batteries issued per year, and other data pertaining to the unit as a whole. The other, approximately 7,000 cards, contains all of the data from the individual questionnaires, such as past experiences with APU's, advantages, disadvantages, items which must be powered by the APU, items willing to be traded off for APU, space and other data. Both of these card decks will be maintained at the Armor Center for future use and as a permanent record of the survey.

(2) These card decks were then transformed into a form more suitable for repeated use by the analysis (data reduction) program. The individual data was stored on a 9 track tape, because of the quantity of information to be stored. The small unit data file was stored in the computer in a faster easier to access disk file.

(3) Both of these data files were accessed by the analysis program specially written to reduce the data in this study. The program contains 1200 FORTRAN statements and completes the data reduction effort in one run. All units are examined together, then each unit is examined alone. For summary purposes the first six pages of the printout contain the averages and/or totals for all units. The individual unit results will be mailed back to units which cooperated in this survey for their information.

(4) Much more information is contained in the printout of results than is required for this APU study. Thus, the entire printout will not be shown in the body of this report but is found in Volume 11. Item 4 under the survey results and Items 11, 12, and 13 under the additional results each total to more than 100 percent. This is not a mistake. These items list advantages, disadvantages, and items to be powered, where the respondents were allowed more than one answer. The respondents were allowed to choose up to 10 items to be powered by the auxiliary power unit, so the percents here could total to 1000 percent if everyone listed 10 items.

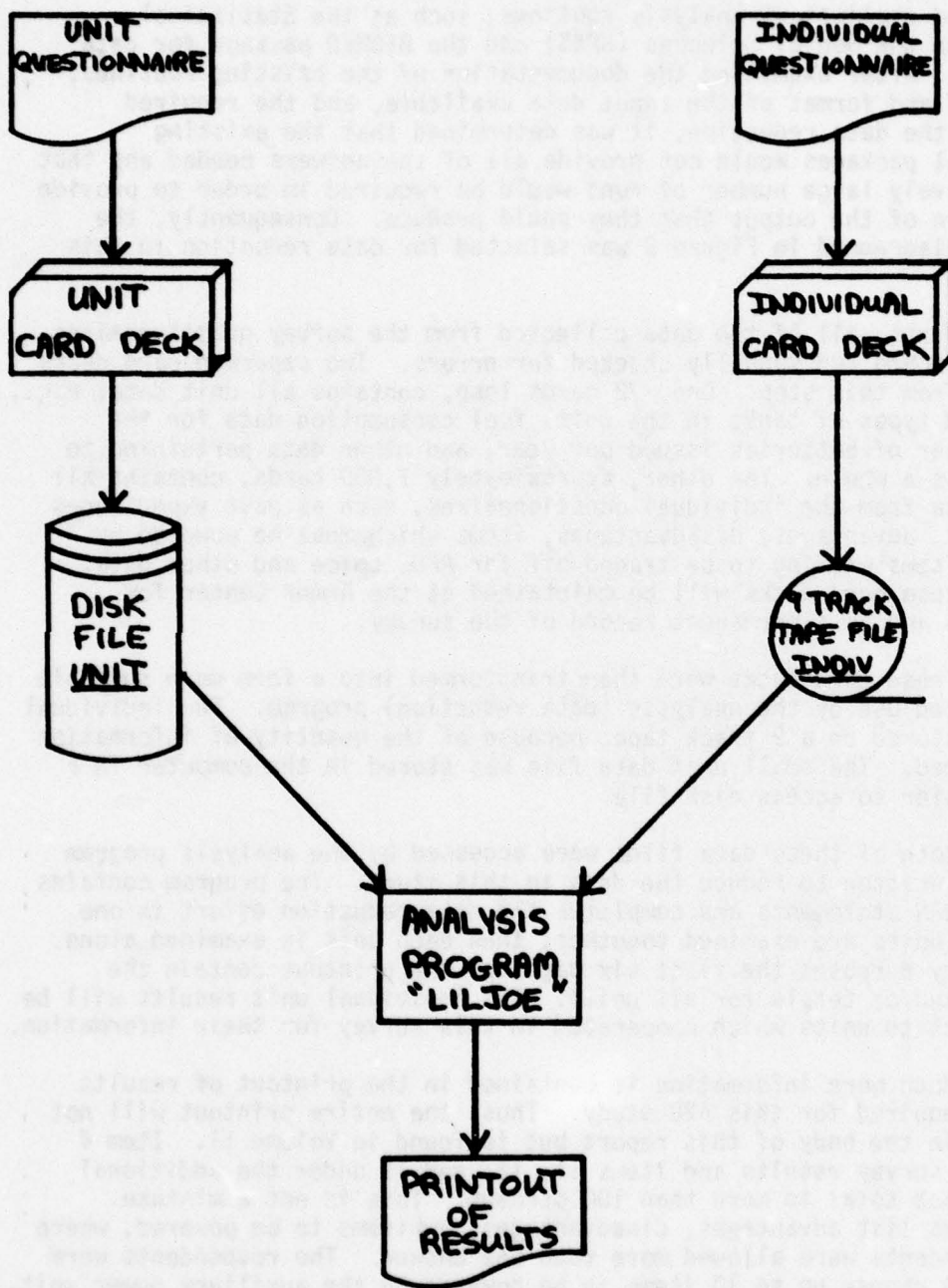


Figure 3. Data reduction approach.

(5) As mentioned earlier, the survey questionnaires and the computer printouts contain much more information than is required for the APU requirements. Thus, the data base and computer printouts of this APU effort will very likely be of value in numerous other studies. The survey conducted for this study provided the vehicle necessary to answer many other questions of interest in the combat developments and training developments arena, e.g., average time in service, in grade, in job, by rank, by unit, how many days per year are spent in battalion level training, company level training, platoon level and individual crew training. In addition to the extensive results from this data reduction effort, the data base itself will be made available to other government agencies upon request. Care was taken to comply with the privacy act, accordingly no names, social security numbers or other personal identification is on the survey questionnaires or data files. Requests should be addressed to US Army Armor Center, Directorate of Combat Developments, ATTN: ATZK-CD-SD, Fort Knox, KY 40121. The data base is saved in several forms, on the original questionnaires, on punched cards, and on computer files and tape at the Data Processing Field Office (DPFO) at Fort Leavenworth, KS. Data file formats and read-only access can be granted upon request.

c. Data Directly Applicable to this Study. Table 1 provides an overview of the survey results that directly reflect the need for an APU.

TABLE 1. OVERVIEW OF THE SURVEY RESULTS

Number of Units Surveyed	29
Number of Individuals Surveyed	740
Favor APU for Tanks	90.7%
Main Advantage	Silent Watch Capability
Main Disadvantage	Extra Maintenance ¹
Main Tradeoff	Personal Equipment Storage
Cold Weather Problem	50% Individuals Said Yes
	54.2% Units Said Yes
Average Hrs/Month Tank Engine Run	14.77 Hrs
Run for Electrical Power Only	8.86 Days/Month
Searchlights	
% of tanks having	90.81%
Hrs/yr operated	32.78 Hrs
Total Gallons of Fuel Used Last Yr	
(24 Units)	2,033,948 gal.
Total Tanks/Total Miles By Type	
M60 (AVLB)	-/1455 mi
M60A1	402/272,260 mil
M60A2	54/27,490 mi
M60A1AOS	441/293,468 mi
M60 RISE	163/194,190 mi
M551	189/88,348 mi
Average No. of Tanks per Bn per Month	
Needing Jump Start.	
Sep-April	32.0
May-August	8.0
Average No. of Batteries/Unit Issued	
Last Yr:	118
Systems which more than 1/3 of	
individuals want powered by APU	Fire Control (88.1%)
	Communications (67.6%)
	Visual Devices (66.1%)
	Environment (43.0%)
	Searchlight (36.4%)

¹The major disadvantage listed was "NONE" (49.5%), extra maintenance was the second disadvantage (34.5%).

SECTION V

RESULTS

V-1. FINDINGS. The results listed in this section answer each of the objectives of this study as written in paragraph I-2 on the basis of the survey data reduction described above.

a. Determine requirement for an APU. More than 90% of the people, who are in Armor units, stated there is a requirement for an APU. This need is further substantiated by the subjective analysis on main engine idle time. Data on main engine running time was obtained from each unit after all survey forms were completed. The survey team asked the following two questions:

QUESTION 1: "Of the total time the tank main engine is running (for whatever reason), what percentage of the time is it operating at idle?"

QUESTION 2: "Of the time expressed in Question 1 (idle time), what percentage of this time is the engine being idled to charge the batteries?"

In response to Question 1, the average was 60%, i.e., of the total time the main engine is running, 60% of the time it is at idle. In response to Question 2, the average was 64%, i.e., of the 60% idle time 64% was devoted to charging the batteries. Therefore, it is concluded that of the total time the main engine is operated, 38.4% ($.60 \times .64$) of the time is devoted to charging the batteries.

b. Identify advantages and disadvantages: When asked to select the single most important advantage of APU's on tanks, more tankers chose added silent watch capability than any other category. This was followed by the second and third most popular advantages of better cold weather starting capability and provision of a battery charging capability. When asked to identify up to 4 disadvantages of mounting an APU in tanks, most (49.5 percent) said they knew of no disadvantages, 34.5 percent stated an APU may add to maintenance problems and 15.9 percent said space would be a problem.

c. Identify benefits an APU would provide. In addition to the advantages listed above, 87.4 percent said that the ability of the APU to heat the crew compartment would be desirable. Noise and thermal signature reductions may improve the survivability of tanks with APU's. And, other notes on several survey forms indicated that it may be possible to use only 4 batteries instead of 6 batteries on each tank. Another, unquantified benefit was that the tank could still fight with the automotive system down.

d. Identify space trade offs necessary to install an APU. This objective recognizes that APU's do not exist on the M60 fleet and are not programmed for the XM-1. Therefore, if an APU is to be applied, a space tradeoff will be necessary. Although the exact dimensions of an APU will not be known until a later phase is completed, tank crewman were asked to identify items to be traded off to gain the necessary space. Personnel equipment stowage, one of four specific choices given, was the leading recommendation for tradeoff. Fifty-three percent selected this choice. Unfortunately, this choice should not have been offered, since no single interior space exists for personnel equipment stowage. The second choice for tradeoff was fuel space, selected by 27%.

e. Determine if tanks and armor units have a "cold weather" starting problem. This question was addressed in several ways by the survey questionnaires. First, battalion/squadron staffs were asked if their units had a cold weather starting problem. Most (54.2 percent) said that they did. When the individuals in those units were asked the same question, exactly half said that they had a cold weather starting problem. The effect of cold weather is also seen in the average number of jump starts required at different times of the year. For the period September to April, the average number of jump starts per month for each battalion was 32, but for May to August only 8 jump starts per month were required in each unit.

f. Determine critical electrical components on a tank that must be operational during "silent watch." The following systems were identified by more than one-third of the survey respondents as necessary for "silent watch"; fire control (88.1%), communication (67.6%), visual devices (66.1%), environmental control (43.0%), and searchlights (36.4%). Other items selected by fewer crewmen were internal lights (17.4%), automotive (13.5%), auxiliary weapons (12.3%), electric or pneumatic wrench (4.7%), CBR devices (3.9%), electrical outlet (2.85%), stove (1.5%) and refue-defuel (1.4%).

g. Determine percentage of time on APU could replace main engine, running time. This number if, of course, dependent upon the generating capacity of the APU and the current drain of the operating systems. If an APU could supply enough current to power all of the devices expected to operate at a given time, then the APU could replace all of the 38.4% idle time for electrical power identified above.

h. Determine the "peacetime profile" for tanks and armor units. The entire peacetime mission profile for tanks can be determined by examining the computer printout contained in Appendix C. Key items of that profile are listed here for easy reference:

-Tank main engine operated during motor stables and routine maintenance: 14.77 hours/mo.

-Tank main engine operated to obtain electrical power for: crew drill, training, etc: 8.86 days/mo.

-Days spent in tactical training per year: 86.

-Days spent on tank gunnery per year: 52.

The average miles per year for each type of tank is as shown in Table 2.

Table 2. AVERAGE TANK MILEAGE

	<u># OF TANKS</u>	<u># OF MILES</u>	<u>AVERAGE MILES/TANK-YR</u>
M60A1	348	272,260.	782.
M60A2	37	27,490.	743.
M60A1AOS	347	293,468.	846.
M60RISE	215	194,190.	903.
M551	<u>126</u>	<u>88,348.</u>	<u>701.</u>
AVERAGE			816.

The numbers in Table 2 may be different than those in Table 1 because a few units listed a number of tanks without a corresponding number of miles. All data was used in Table 1, however, in Table 2 only tanks listed with the corresponding number of miles were used. This will result in more accurate averages for the miles per tank each year column.

SECTION VI

CONCLUSIONS

VI-1. GENERAL. The results of the survey indicate a requirement for an APU on main battle tanks. Prior to initiation of the survey, alternative solutions to the increasing electrical demand problem were examined subjectively. The following were considered:

- more batteries.
- better batteries.
- means of heating the batteries.
- larger alternator/generator.

All of the foregoing were rejected individually and collectively since it does not appear that any or all of these measures would provide a total solution. Better batteries and a means to heat the batteries in cold weather should be pursued whether or not an APU is fielded. Additionally, any APU engine that did not burn the same fuel as the tank main engine was rejected as being too great a logistics burden.

VI-2. RATIONALE AND JUSTIFICATION. Listed below are the primary reasons the Armor Center believes an APU should be installed on main battle tanks.

a. Common Rationale (XM-1 and M60 series):

(1) Enhanced "Silent Watch" capability. The ability to have a "live turret" with all electrical systems on, without running the main engine, is the one single major tactical advantage for an APU. Inherent is the advantage of charging/recharging the tank batteries without running the main engine. The additional benefits derived by having an APU vis-a-vis running the main engine, are a significant reduction in noise and thermal signatures.

(2) Less Wear and Tear on the Tank Main Engine. The high percentage of time (60%) the tank main engine is run at idle has a definite effect upon the life of the engine. While this effect is not quantified or measured by this study effort, there is a universal agreement by knowledgeable personnel (engineers, and maintenance personnel) that a large amount of engine problems can be attributed to excessive idling. While an APU will never replace all of the main engine idle time, it can significantly reduce it.

(3) Personnel Heater. Since 70% of the personnel surveyed are not satisfied with the current personnel heater, an APU that could also provide heat (such as gas turbine with a heat exchanger) should be investigated. The APU-heater combination must be carefully evaluated on a cost-benefit basis with the logical alternative of procuring a better heater.

(4) Turret Electrical Power - During Scheduled Maintenance. Whenever the main engine is "pulled" during scheduled maintenance, there is no electrical power available in the turret. This situation occurs 57% of the time. Hence, electrical systems in the turret also requiring maintenance can not be worked upon concurrently. An APU would remedy this situation.

(5) Prolonged Battery Life. A large percentage (62.5%) of the units stated they have a battery problem. While an APU certainly would not correct the entire problem, most knowledgeable personnel subjectively believe if batteries were kept "charged up" the problem would be reduced significantly.

b. Rationale Peculiar to XM-1. The over-riding rationale for an APU on the XM-1 is fuel economy at idle. Compared to a diesel engine; a turbine consumes much more fuel at idle. Considering the main engine of a tank operates about 60% of the time at idle, and about 38% of the total time at idle is devoted to charging the batteries - there is a great potential for fuel economy. It must be assumed that any APU procured would burn less fuel per hour than the tank main engine (turbine only) at idle.

c. Rationale Peculiar to the M60 Series. The over-riding rationale for an APU on the M60 series is to provide a cold weather start capability. As brought out earlier in this report, cold weather starting problems exist. The adoption of an APU would virtually solve all cold weather starting problems on the M60 fleet. Further, the APU would eliminate to a large degree, current SOP's that require the main engine to be started on a frequent basis, during cold weather.

SECTION VII

RECOMMENDATIONS

VII-1. GENERAL. This analysis and the opinion of the "users in the field" strongly supports the adoption of an APU on main battle tanks. Certain rationale in Section V can be quantified, many can not. In the final analysis, a "silent watch" capability in combat, and potential fuel economy in peacetime justify an APU.

VII-2. RECOMMENDATIONS.

a. That USAARMC in conjunction with TARADCOM, PM DOD Mobile Electric Power, PM's M60 and XM-1 - expedite the development and procurement of an APU for main battle tanks.

b. That, if possible, a common APU for both M60 and XM-1 tanks be fielded.

c. That DOD PM Mobile Electric Power, in conjunction with TRADOC proponents, consider the requirement for an APU on other combat vehicles.

APPENDIX A - INDIVIDUAL SURVEY FORM

QUESTIONNAIRE TO DETERMINE IF A REQUIREMENT FOR AN APU ("LITTLE JOE")
EXISTS FOR TANKS

BACKGROUND

The Armor Center, PM XM-1, PM M60 and TARADCOM are currently conducting a study to determine if there is a requirement for an auxiliary power unit (APU) for tanks. The system under evaluation is similar to the old concept of the "Little Joe" found on pre-M48A2 series tanks and on the current M88 VTR. This APU is envisioned to provide Electrical Power Only, it is not to be an alternate source of propulsion. It would consist of a self-contained power source of approximately 15-30 gross horsepower capable of running on the same fuels and lubricants as the main engine and a suitable electric generator of compatible capacity (8-16 net KW @ 75 percent efficiency). The entire system would be capable of being installed within the current armor envelope of the vehicle with no more than minor internal reconfiguration and no degradation to any currently established crew or equipment performance level.

SECTION I - PERSONAL DATA

	YEARS	MONTHS
(1) RANK _____		
(2) TIME IN GRADE	_____	_____
(3) LENGTH OF ACTIVE SERVICE	_____	_____
(4) ASSIGNMENT HISTORY: CONUS	_____	_____
GERMANY	_____	_____
KOREA	_____	_____
VIETNAM	_____	_____
HAWAII	_____	_____
OTHER (SPECIFY)	_____	_____
_____	_____	_____

YEARS MONTHS

(5) PRESENT JOB TITLE _____

(6) NUMBER OF MONTHS IN PRESENT JOB _____

(7) DMOS _____ (8) MONTHS DMOS QUALIFIED _____

(9) PMOS _____ (10) MONTHS PMOS QUALIFIED _____

(11) HOW WAS PMOS OBTAINED?

CHECK: _____ SCHOOL

_____ OJT

_____ OTHER (SPECIFY)

(12) HAVE YOU SERVED IN YOUR PMOS IN COMBAT?

CHECK: _____ YES

_____ NO

(13) WHERE? _____

(14) SMOS _____

(15) LIST YOUR LAST FIVE DUTY ASSIGNMENTS AND UNITS, BEGINNING WITH MOST RECENT ASSIGNMENT PRIOR TO YOUR PRESENT ASSIGNMENT.

DUTY POSITION

UNIT

INSTRUCTIONS

Answer the questions in Sections II, III and IV on the basis of your knowledge of tanks, total Army experience, and experience in your present assignment. The questions in these three sections are to be answered, as nearly as possible, from the viewpoint of the tank commander or in terms of the individual tanks assigned to you as a unit leader/staff officer.

SECTION II - GENERAL

1. HOW MANY TANKS, AND WHAT TYPE, ARE IN YOUR UNIT?

_____ M60
_____ M60A1
_____ M60A2
_____ M60A3
_____ M60 (RISE)
_____ M551 AR/AAV

NOTE: If your unit presently is equipped with the M551 AR/AAV, assume in answering the following questions that they have been replaced with the M60A1 MBT under the new Armored Cavalry Platoon TOE.

2. HAVE YOU EVER SERVED WITH TANKS THAT HAD AN APU (E.G., M4A3E8, M41, M48 SERIES)?

CHECK: _____ YES (ANSWER QUES 3)
_____ NO (SKIP TO QUES 5)

3. WHAT WERE THE MAJOR ADVANTAGES OF THE APU?

4. WHAT WERE THE MAJOR DISADVANTAGES OF THE APU?

5. DO YOU THINK TANKS SHOULD BE EQUIPPED WITH AN APU?

CHECK: _____ YES

_____ NO

6. WHY OR WHY NOT? _____

7. FOLLOWING ARE SOME POSSIBLE BENEFITS OF EQUIPPING TANKS WITH AN APU. RANK THE BENEFITS BY NUMBER IN TERMS OF THEIR IMPORTANCE TO YOU (1 - MOST IMPORTANT, 2 - NEXT MOST IMPORTANT, AND SO ON).

RANK: _____ NOISE REDUCTION

_____ IR, THERMAL SIGNATURE REDUCTION

_____ IMPROVED FUEL ECONOMY

_____ SOURCE OF ELECTRICAL ENERGY TO AID IN COLD WEATHER STARTING

_____ SOURCE OF HEAT TO WINTERIZE TANK

_____ MEANS OF CHARGING VEHICLE BATTERIES

_____ MEANS OF PROVIDING POWER TO OPERATE TANK SYSTEMS NECESSARY TO ENGAGE TARGETS IN A NIGHT DEFENSIVE POSITION WITHOUT RUNNING THE MAIN ENGINE

_____ OTHER (SPECIFY) _____

8. WHAT DISADVANTAGES WOULD YOU SEE IN HAVING AN APU ON TANKS?

9. IF HAVING AN APU MEANS REDUCING ENGINE COMPARTMENT OR CREW COMPARTMENT SPACE, WHICH ONE OF THE FOLLOWING WOULD YOU RECOMMEND GIVING UP?

CHECK: ☐ FUEL SPACE
☐ AMMO STOWAGE
☐ PERSONNEL HEATER
☐ PERSONAL EQUIPMENT STOWAGE
☐ OTHER (SPECIFY)

SECTION III - USES FOR AN APU

10. ON THE AVERAGE, HOW MANY HOURS EACH MONTH IS THE TANK MAIN ENGINE OPERATED DURING MOTOR STABLES, ROUTINE MAINTENANCE, BEFORE OPERATIONS CHECK:

☐ LESS THAN 10
☐ 11-15
☐ 16-20
☐ 21-25
☐ MORE THAN 26

11. IS YOUR TANK EQUIPPED WITH A SEARCHLIGHT?

CHECK: ☐ YES (ANSWER QUES 13)
☐ NO (SKIP TO QUES 14)

12. IN THE LAST YEAR, HOW MANY HOURS WAS THE SEARCHLIGHT USED WHILE THE TANK WAS STATIONARY?

HOURS

13. ON THE AVERAGE, HOW MANY DAYS EACH MONTH IS THE TANK MAIN ENGINE RUN TO MAKE ELECTRICAL POWER AVAILABLE FOR CREW DRILL/TRAINING, COMMO TRAINING, ETC?

CHECK: _____ 1 OR 2 DAYS

_____ 3 TO 5

_____ 6 TO 10

_____ 11 TO 15

_____ 16 TO 20

14. DOES YOUR TANK HAVE A COLD WEATHER STARTING PROBLEM?

CHECK: _____ YES (ANSWER QUES 16-17)

_____ NO (SKIP TO QUES 18)

15. HOW MANY DAYS IN THE LAST YEAR DID YOU EXPERIENCE A COLD WEATHER STARTING PROBLEM?

_____ DAYS

16. ON WHAT PERCENTAGE OF THOSE DAYS WAS A "SLAVE" OR "JUMP" NEEDED TO GET THE TANK STARTED?

CHECK: _____ 0-10%

_____ 11-20%

_____ 21-30%

_____ 31-50%

_____ 51-70%

_____ 71-80%

_____ 81-90%

_____ MORE THAN 90%

17. WHY WAS THE "SLAVE" OR "JUMP" USUALLY NEEDED?

CHECK: ☐ COLD WEATHER
☐ WEAK OR FAULTY BATTERIES
☐ OTHER (SPECIFY)

18. DOES YOUR TANK HAVE A PERSONNEL HEATER?

CHECK: ☐ YES (ANSWER QUES 20-22)
☐ NO (SKIP TO QUES 24)

19. WHEN NEEDED, WHAT PERCENTAGE OF THE TIME DOES THE PERSONNEL HEATER WORK?

CHECK: ☐ 0-10%
☐ 11-20%
☐ 21-40%
☐ 41-60%
☐ MORE THAN 60%

20. HOW WELL DOES THE PERSONNEL HEATER WORK?

CHECK: ☐ VERY WELL
☐ FAIRLY WELL
☐ POORLY
☐ VERY POORLY
☐ NOT AT ALL

21. WHAT COMMENTS DO YOU HAVE ABOUT THE PERSONNEL HEATER?

22. IF THE APU HAD THE CAPABILITY TO ALSO FUNCTION AS A PERSONNEL HEATER, WOULD YOU WANT AN APU FOR THE TANK?

CHECK: _____ YES

_____ NO

23. WHY OR WHY NOT? _____

24. THE PRIMARY FUNCTION OF AN APU IS TO RECHARGE TANK BATTERIES AND PROVIDE ELECTRICAL POWER WHEN THE MAIN ENGINE IS NOT RUNNING. LIST THE ELECTRICAL SYSTEMS ON YOUR TANK (TANKS) YOU WOULD WANT POWERED.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

25. WHAT OTHER SYSTEMS, IF ANY, WOULD YOU LIKE TO HAVE POWERED BY AN APU?

a. _____

b. _____

c. _____

d. _____

SECTION IV - APU USE IN COMBAT AND FIELD EXERCISES

26. DURING NIGHT OPERATIONS, ARE YOU OR WOULD YOU BE CONCERNED ABOUT THE NOISE MADE BY THE TANK MAIN ENGINE?

CHECK: _____ YES

_____ NO

27 WHY OR WHY NOT? _____

28. ARE YOU CONCERNED ABOUT THE THERMAL/IR SIGNATURE OF THE MAIN ENGINE?

CHECK: _____ YES

_____ NO

29. WHY OR WHY NOT? _____

30. IN THE COURSE OF A NORMAL 24-HOUR PERIOD OF AN FTX, HOW MANY HOURS IS THE MAIN ENGINE OPERATED ONLY TO RECHARGE BATTERIES?

CHECK: _____ 0-1 HOURS

_____ 4-5 HOURS

_____ 2-3 HOURS

_____ MORE THAN 6 HOURS

31. WHEN IN A NIGHT DEFENSIVE BATTLE POSITION, WHAT SYSTEMS ARE ON TO INSURE THE TANK IS READY TO ENGAGE TARGETS AND WHAT PROCEDURES DO YOU USE TO KEEP THE BATTERIES CHARGED?

SYSTEMS ON _____

PROCEDURES _____

32. HOW DO THESE PROCEDURES CHANGE DURING COLD WEATHER? _____

33. IF THE TANK HAD AN APU TO MAINTAIN THE CHARGE OF BATTERIES AND PERMIT OPERATIONS OF HEATERS, COMMUNICATIONS, NIGHT VISION, TURRET POWER AND FIRE CONTROL SYSTEMS, HOW WOULD THE PROCEDURES DESCRIBED IN THE ANSWER TO QUESTION 31 BE CHANGED?

SECTION I - UNIT LEADERS

NOTE: THE FOLLOWING QUESTIONS ARE TO BE ANSWERED ONLY BY PLATOON COMPANY/TROOP, AND BATTALION/SQUADRON OFFICERS AND NCO'S. INDIVIDUAL TANK COMMANDERS WILL NOT ANSWER THE QUESTIONS.

34. HOW MANY DAYS IN THE LAST YEAR DID YOUR UNIT (PLT, CO/TRP, BN/SQDN) SPEND IN TACTICAL TRAINING WITH THE TANKS MOVING (ARTEP, FTX, ALERTS, ETC)?

_____ DAYS

35. HOW MANY OF THOSE DAYS WERE SPENT IN:

BATTALION LEVEL TRAINING? _____ DAYS

COMPANY LEVEL TRAINING? _____ DAYS

PLATOON LEVEL TRAINING? _____ DAYS

INDIVIDUAL CREW TRAINING? _____ DAYS

36. HOW MANY DAYS IN THE LAST YEAR DID YOUR UNIT SPEND IN TANK GUNNERY TRAINING (TANKS USED WITH ENGINES ON)?

_____ DAYS

37. HOW MANY OF THOSE DAYS WERE SPENT ON?

STATIONARY TANK RANGES? _____ DAYS

STATIONARY TANK NIGHT RANGES? _____ DAYS

APPENDIX B - UNIT QUESTIONNAIRE

UNIT QUESTIONNAIRE

1. What model tank(s), and how many of each model, are in your unit?

_____ M60
_____ M60A1
_____ M60A2
_____ M60A1 AOS
_____ M60 (Rise)
_____ M551 AR/AAV

2. How many days of tactical training (ARTEP, FTX, ALERTS, etc.) has your unit experienced in the past year? _____ days.

3. How many of those days were spent on:

Battalion level training? _____ days

Company level training? _____ days

Platoon level training? _____ days

4. How many days was your unit involved in tank gunnery training (vehicles used with engines on) in the last year? _____ days.

5. What was the temperature range (degrees F) in your area:

In the past Year: _____ Low _____ High _____ Average

From Sep to Apr: _____ Low _____ High _____ Average

From May to Aug: _____ Low _____ High _____ Average

6. Does your unit have a cold weather starting problem?

_____ Yes

_____ No

7. Approximately how many tanks per month have to be "slaved" or "jumped" to get started? _____ Sep to Apr

_____ May to Aug

Incl 1

8. How many gallons of fuel were used by tanks in your unit last year?

_____ gals.

9. What is the average fuel consumption per tank/month? _____

10. How often does your unit perform "Q" service which involves pulling the main engine of your tanks? _____ times per year.

11. What is the average percentage of time the tank engine is not hooked up during "Q" service? _____ %

12. If an APU were on your tanks that would permit turret systems to be operated without the main engine installed in the hull, would this significantly increase the amount of turret maintenance pulled on tanks during "Q" services? _____ Yes _____ No. Why or Why not? _____

13. What is the total mileage accumulated on your tanks in the last year by type tank?

<u>TYPE TANK</u>	<u>MILES/YEAR</u>
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

14. Does your unit have a tank battery problem? For example, do you DX
a considerable number of batteries for tanks during the winter months?

YES _____ NO _____

PLEASE EXPLAIN _____

15. HOW MANY BATTERIES DID YOUR UNIT ISSUE TO TANKS IN THE LAST YEAR?

_____ BATTERIES

APPENDIX C - SURVEY RESULTS

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AUXILIARY POWER UNIT (APU) FOR TANKS
SURVEY RESULTS
ALL

	LTC	MAJ	CPT	LT	WO	E-7	E-6	OTHER	TOTAL
1. NUMBER	19	24	89	151	12	106	261	78	740
2. A FAVOR APU	17	21	79	139	11	96	232	72	667
	89.5%	91.3%	89.8%	92.7%	91.7%	90.6%	89.6%	92.3%	90.7%
B OPPOSE APU	2	2	9	11	1	10	27	6	68
	10.5%	8.7%	10.2%	7.3%	8.3%	9.4%	10.4%	7.7%	9.3%
3. MAIN ADVANTAGE									
A NOISE RED	2	3	7	19	0	11	29	12	83
	10.5%	12.5%	7.9%	12.6%	0.0%	10.4%	11.1%	15.4%	11.2%
B SIGN. RED	0	1	7	7	0	2	10	2	29
	0.0%	4.2%	7.9%	4.6%	0.0%	1.9%	3.8%	2.6%	3.9%
C FUEL ECON	1	0	4	2	0	12	24	7	50
	5.3%	0.0%	4.5%	1.3%	0.0%	11.3%	9.2%	9.0%	6.8%
D COLD START	2	3	17	27	7	18	70	15	159
	10.5%	12.5%	19.1%	17.9%	58.3%	17.0%	26.8%	19.2%	21.5%
E HEAT	0	0	1	1	0	2	9	4	17
	0.0%	0.0%	1.1%	.7%	0.0%	1.9%	3.4%	5.1%	2.3%
F CHARGE BAT	3	4	14	19	1	18	33	8	100
	15.8%	16.7%	15.7%	12.6%	8.3%	17.0%	12.6%	10.3%	13.5%
G NIGHT DEF	10	12	37	73	3	49	99	41	324
	52.6%	50.0%	41.6%	48.3%	25.0%	46.2%	37.9%	52.6%	43.8%
H OTHER	0	1	4	3	1	1	4	0	14
	0.0%	4.2%	4.5%	2.0%	8.3%	.9%	1.5%	0.0%	1.9%
4. DISADVANTAGES									
A MAINTENANCE	11	16	48	69	6	19	64	22	255
	57.9%	66.7%	53.9%	45.7%	50.0%	17.9%	24.5%	28.2%	34.5%
B SPACE	2	5	19	32	2	10	37	11	118
	10.5%	20.8%	21.3%	21.2%	16.7%	9.4%	14.2%	14.1%	15.9%
C FUEL	1	2	8	5	0	2	8	2	28
	5.3%	8.3%	9.0%	3.3%	0.0%	1.9%	3.1%	2.6%	3.8%
D NONE	6	5	26	60	5	69	152	43	366
	31.6%	20.8%	29.2%	39.7%	41.7%	65.1%	58.2%	55.1%	49.5%
E OTHER	7	4	12	19	4	13	25	7	91
	36.8%	16.7%	13.5%	12.6%	33.3%	12.3%	9.6%	9.0%	12.3%
5. TRADEOFFS									
A FUEL	5	5	24	38	4	35	72	13	196
	26.3%	20.8%	27.0%	25.2%	33.3%	33.0%	27.6%	16.7%	26.5%
B AMMUN	1	2	1	4	0	3	11	4	26
	5.3%	8.3%	1.1%	2.6%	0.0%	2.8%	4.2%	5.1%	3.5%
C HEATER	3	1	14	14	0	9	16	8	65
	15.8%	4.2%	15.7%	9.3%	0.0%	8.5%	6.1%	10.3%	8.8%
D PERSONAL EQ	9	13	43	83	7	55	140	44	394
	47.4%	54.2%	48.3%	55.0%	58.3%	51.9%	53.6%	56.4%	53.2%
E OTHER	0	2	6	10	1	3	20	7	49
	0.0%	8.3%	6.7%	6.6%	8.3%	2.8%	7.7%	9.0%	6.6%
6. COLD WEATHER									
A PROBLEM	11	11	52	68	6	55	132	35	370
	57.9%	45.8%	58.4%	45.0%	50.0%	51.9%	50.6%	44.9%	50.0%
B NO PROBLEM	8	13	37	83	6	51	129	43	370
	42.1%	54.2%	41.6%	55.0%	50.0%	48.1%	49.4%	55.1%	50.0%

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PEACETIME OPERATIONAL PROFILE

ALL

	LTC	MAJ	CPT	LT	WO	E-7	E-6	OTHER	TOTAL
1. PERSONNEL									
A NUMBER	19	24	89	151	12	106	261	78	740
B AVG YRS IN G	2.40	3.93	2.87	1.21	2.64	3.16	3.01	1.91	2.54
C AVG YRS SERV	18.28	13.07	7.27	2.15	16.80	15.38	8.70	5.65	8.35
D AVG MO IN JB	9.95	8.42	8.49	9.79	22.08	19.27	17.72	15.47	14.55
2. HOURS/MONTH									
A LESS THAN 10	5	3	20	38	4	31	61	17	179
B 11 TO 15	8	12	26	50	3	22	74	28	223
C 16 TO 20	4	5	21	35	0	24	71	20	180
D 21 TO 25	2	1	11	10	4	11	25	7	71
E MORE THAN 26	0	3	9	12	1	17	28	6	76
F MEAN	13.00	15.33	15.01	13.95	14.92	15.26	15.07	14.59	14.77
G STANDARD DEV	5.87	6.26	7.14	6.86	8.70	8.15	7.14	6.64	7.15
3. SEARCHLIGHT									
A NUMBER	18	21	78	144	11	94	236	70	672
B PERCENT	94.74	87.50	87.64	95.36	91.67	88.68	90.42	89.74	90.81
C MEAN HRS/YR	20.53	19.05	36.40	32.74	13.00	32.47	35.70	27.26	32.78
D STANDARD DEV	26.98	23.93	120.89	73.78	21.76	63.49	55.33	30.74	68.64
4. ELECT POWER									
A 1 OR 2	2	4	14	16	1	12	27	11	87
B 3 TO 5	5	9	18	52	2	29	46	20	181
C 6 TO 10	8	5	24	41	4	24	75	15	196
D 11 TO 15	3	4	16	22	0	17	55	17	134
E 16 TO 20	1	2	12	16	2	21	55	15	124
F MEAN	7.58	7.08	8.44	7.71	8.61	8.98	9.80	9.07	8.86
G STANDARD DEV	4.32	5.08	5.45	5.00	5.82	5.77	5.55	5.83	5.50
5. TACTICAL ING.									
A AVERAGE DAYS	107.00	87.00	66.00	69.00	120.00	93.00	92.00	99.00	80.00
B STANDARD DEV	109.46	75.46	52.19	59.47	381.84	85.53	171.82	244.91	95.65
6. TRAINING LEVEL									
A BATTALION									
1. MEAN	20.00	27.00	22.00	27.00	12.00	32.00	48.00	30.00	30.00
2. STANDARD DEV	32.13	24.69	25.36	29.01	41.87	34.75	99.74	79.27	44.12
B COMPANY									
1. MEAN	23.00	35.00	24.00	23.00	22.00	44.00	37.00	47.00	31.00
2. STANDARD DEV	29.39	30.49	25.60	25.45	76.50	46.62	70.80	117.80	42.01
C PLATOON									
1. MEAN	26.00	31.00	17.00	13.00	15.00	23.00	21.00	21.00	18.00
2. STANDARD DEV	35.59	43.46	24.52	16.80	51.96	33.64	40.88	58.59	29.51
D IND CREW									
1. MEAN	29.00	18.00	17.00	9.00	37.00	12.00	23.00	23.00	15.00
2. STANDARD DEV	38.86	28.34	29.85	20.11	128.46	15.18	57.31	66.88	30.86
7. TANK GUNNERY									
A MEAN	51.00	61.00	42.00	30.00	20.00	38.00	29.00	19.00	35.00
B STANDARD DEV	38.86	39.26	32.17	22.58	69.28	32.42	55.20	46.11	40.29
8. GUNNERY RANGE									
A STATIONARY									
1. MEAN	28.00	45.00	19.00	14.00	3.00	20.00	13.00	7.00	18.00
2. STANDARD DEV	25.62	72.89	21.55	13.47	10.39	21.80	25.31	17.32	27.40
B NIGHT									
1. MEAN	17.00	41.00	13.00	13.00	3.00	15.00	12.00	6.00	14.00
2. STANDARD DEV	15.87	72.15	12.89	13.82	10.39	18.93	23.20	14.95	23.63

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9. TOTAL GALLONS
OF FUEL = 2033948.

10. AVERAGE FUEL
PER TANK PER
MONTH = 233.5

11. AVERAGE ENGINE
PULLS PER UNIT = 6.0

12. AVERAGE % OF
THE TIME ENGINE
NOT HOOKED UP = 57.00

13. TOTAL TANKS/
TOTAL MILES

M60	0/	1455.
M60A1	402/	272260.
M60A2	54/	27490.
M60A1ADS	389/	293468.
M60R1SE	215/	194190.
M551	189/	88348.

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ADDITIONAL DATA

1. AVERAGE TEMPERATURE RANGE

A PAST YEAR LOW= 6.8 HIGH= 86.7 AVERAGE= 53.7
B SEPT-APRIL LOW= 6.9 HIGH= 68.8 AVERAGE= 43.7
C MAY-AUGUST LOW= 65.8 HIGH= 84.0 AVERAGE= 65.8

2. % OF UNITS WITH COLD WEATHER STARTING PROBLEM= 54.2

3. AVERAGE NUMBER OF TANKS PER BN PER MONTH WHICH NEED JUMP START
SEP-APRIL= 32.0 MAY-AUGUST= 8.0

LTC MAJ CPT LT WO E-7 E-6 OTHER TOTAL

4. DAYS COLD WX

START PROBLEM

A MEAN 31.00 21.00 32.00 33.00 47.00 23.00 29.00 28.00 29.00
B STANDARD DEV 42.87 34.49 44.55 63.86 65.03 32.84 43.36 43.41 46.22

5. % OF DAYS IN 4

REQ. JUMP

A 0-10% 4 7 11 18 2 16 34 11 103
B 11-20% 3 0 4 6 0 3 17 3 36
C 21-30% 2 0 4 9 0 7 12 7 41
D 31-50% 1 0 11 10 3 11 32 3 71
E 51-70% 2 4 9 4 1 8 19 4 51
F 71-80% 0 0 6 14 0 5 14 6 45
G 81-90% 0 0 3 8 1 6 15 5 38
H MORE THAN 90 1 1 9 12 0 11 21 5 60
I MEAN 37.40 37.20 60.29 60.62 46.25 62.16 57.84 58.79 58.03
J STANDARD DEV 33.95 37.75 38.08 40.64 32.39 42.37 38.71 42.00 39.47

6. WHY NEED JUMP

A COLD WX

7 9 40 50 2 38 98 23 267
58.3% 64.3% 65.6% 58.1% 22.2% 55.1% 56.6% 51.1% 56.9%
B WEAK BATTERY 5 3 16 32 5 28 57 20 167
41.7% 21.4% 26.2% 37.2% 66.7% 40.6% 32.9% 44.4% 35.6%
C OTHER 0 2 5 4 1 3 18 2 35
0.0% 14.3% 8.2% 4.7% 11.1% 4.3% 10.4% 4.4% 7.5%

7. TANK HEATER

A YES

17 19 79 129 10 89 221 68 632
89.5% 79.2% 88.8% 85.4% 83.3% 84.0% 84.7% 87.2% 85.4%
B NO 2 5 10 22 2 17 39 10 107
10.5% 20.8% 11.2% 14.6% 16.7% 16.0% 14.9% 12.8% 14.5%

8. HEATER WORKS

A VERY WELL

9 6 23 39 0 28 76 17 198
56.3% 30.0% 29.1% 28.5% 0.0% 30.8% 32.6% 24.6% 30.3%
B FAIR 7 9 38 55 4 28 75 30 246
43.8% 45.0% 48.1% 40.1% 50.0% 30.8% 32.2% 43.5% 37.7%
C POOR 0 4 7 23 3 15 26 10 88
0.0% 20.0% 8.9% 16.8% 37.5% 16.5% 11.2% 14.5% 13.5%
D VERY POOR 0 1 8 8 1 7 16 3 44
0.0% 5.0% 10.1% 5.8% 12.5% 7.7% 6.9% 4.3% 6.7%
E NOT AT ALL 0 0 3 12 0 13 40 9 77
0.0% 0.0% 3.8% 8.8% 0.0% 14.3% 17.2% 13.0% 11.8%

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9. % OF TIME WORK									
A 0-10%	2	1	6	23	2	25	52	19	130
B 11-20%	1	1	7	12	2	9	28	9	69
C 21-40%	0	4	13	19	3	6	31	10	86
D 41-60%	5	4	18	22	3	19	37	12	120
E MORE THAN 60	8	7	33	49	0	31	70	20	218
F MEAN	54.0	47.6	51.7	45.8	28.4	43.7	41.2	40.4	44.1
G STANDARD DEV	27.1	25.2	26.4	29.5	18.0	31.5	30.1	30.7	29.7
10. APU PLUS HEAT									
A DESIRABLE	15	23	79	139	11	85	231	63	666
	78.9%	95.8%	88.8%	92.1%	91.7%	81.0%	88.5%	80.8%	87.4%
B NOT DES.	4	1	10	12	1	20	30	15	93
	21.1%	4.2%	11.2%	7.9%	8.3%	19.0%	11.5%	19.2%	12.6%
11. SYSTEMS WANT POWERED BY APU									
A COMMUNICATE	15	20	74	121	8	63	148	51	500
	78.9%	83.3%	83.1%	80.1%	66.7%	59.4%	56.7%	65.4%	67.6%
B ENVIRONMENT	6	9	39	68	3	38	123	32	318
	31.6%	37.5%	43.8%	45.0%	25.0%	35.8%	47.1%	41.0%	43.0%
C FIRE CONTROL	17	20	81	143	9	92	225	65	652
	89.5%	83.3%	91.0%	94.7%	75.0%	86.8%	86.2%	83.3%	88.1%
D VISUAL DEV	12	15	57	98	8	60	183	56	489
	63.2%	62.5%	64.0%	64.9%	66.7%	56.6%	70.1%	71.8%	66.1%
E AUTOMOTIVE	2	6	16	21	4	10	28	13	100
	10.5%	25.0%	18.0%	13.9%	33.3%	9.4%	10.7%	16.7%	13.5%
F AUX WEAPONS	4	6	10	14	0	12	36	9	91
	21.1%	25.0%	11.2%	9.3%	0.0%	11.3%	13.8%	11.5%	12.3%
G WRENCH	0	1	5	9	1	1	16	2	35
	0.0%	4.2%	5.6%	6.0%	8.3%	.9%	6.1%	2.6%	4.7%
H RE-DEFUEL	0	0	4	6	0	0	0	0	10
	0.0%	0.0%	4.5%	4.0%	0.0%	0.0%	0.0%	0.0%	1.4%
I COFFEE POT	0	1	0	0	0	0	0	0	1
	0.0%	4.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	.1%
J STOVE	0	4	2	5	0	0	0	0	11
	0.0%	16.7%	2.2%	3.3%	0.0%	0.0%	0.0%	0.0%	1.5%
K REFRIGERATOR	0	0	0	0	0	0	1	0	1
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	.4%	0.0%	.1%
L LIGHTS INT	2	2	15	29	3	16	48	17	132
	10.5%	8.3%	16.9%	19.2%	25.0%	15.1%	18.4%	21.8%	17.8%
M SEARCH LIGHT	7	6	29	58	5	34	105	25	269
	36.8%	25.0%	32.6%	38.4%	41.7%	32.1%	40.2%	32.1%	36.4%
N AUX POWER	2	0	2	4	0	2	8	3	21
	10.5%	0.0%	2.2%	2.6%	0.0%	1.9%	3.1%	3.8%	2.8%
O CBR DEVICES	0	1	3	9	0	2	14	0	29
	0.0%	4.2%	3.4%	6.0%	0.0%	1.9%	5.4%	0.0%	3.9%
P RADAR	0	0	2	0	0	0	0	0	2
	0.0%	0.0%	2.2%	0.0%	0.0%	0.0%	0.0%	0.0%	.3%
Q ELECTRIC OUT	0	0	3	5	0	0	9	4	21
	0.0%	0.0%	3.4%	3.3%	0.0%	0.0%	3.4%	5.1%	2.8%
R OTHER	63	51	53	39	22	14	0	0	242
	331.6%	212.5%	59.6%	25.8%	183.3%	13.2%	0.0%	0.0%	32.7%
12. ADVANTAGES									
A NOISE RED.	4	3	2	1	0	8	11	2	31
	21.1%	12.5%	2.2%	.7%	0.0%	7.5%	4.2%	2.6%	4.2%
B SIGN. RED.	0	0	0	1	0	0	0	0	1
	0.0%	0.0%	0.0%	.7%	0.0%	0.0%	0.0%	0.0%	.1%
C FUEL ECON.	7	4	5	1	1	9	21	2	50
	36.8%	16.7%	5.6%	.7%	8.3%	8.5%	8.0%	2.6%	6.8%
D COLD START	9	8	8	0	0	14	17	4	60
	47.4%	33.3%	9.0%	0.0%	0.0%	13.2%	6.5%	5.1%	8.1%
E HEAT	1	2	1	0	0	1	4	0	9
	5.3%	8.3%	1.1%	0.0%	0.0%	.9%	1.5%	0.0%	1.2%
F CHARGE BAT.	10	10	8	1	1	30	38	5	103
	52.6%	41.7%	9.0%	.7%	8.3%	28.3%	14.6%	6.4%	13.9%

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G NIGHT DEF.	1	1	0	0	0	9	3	1	15
	5.3%	4.2%	0.0%	0.0%	0.0%	8.5%	1.1%	1.3%	2.0%
H OTHER	3	5	3	0	1	11	12	2	37
	15.8%	20.8%	3.4%	0.0%	8.3%	10.4%	4.6%	2.6%	5.0%
13. DISADVANTAGES									
A. MAINTENANCE	8	10	10	0	0	14	23	1	66
	42.1%	41.7%	11.2%	0.0%	0.0%	13.2%	8.8%	1.3%	8.9%
B SPACE	0	2	1	0	0	3	2	0	8
	0.0%	8.3%	1.1%	0.0%	0.0%	2.8%	.8%	0.0%	1.1%
C FUEL	2	0	1	0	0	0	3	1	7
	10.5%	0.0%	1.1%	0.0%	0.0%	0.0%	1.1%	1.3%	.9%
D NONE	5	14	77	150	10	82	225	75	438
	26.3%	58.3%	86.5%	99.3%	83.3%	77.4%	86.2%	96.2%	86.2%
E OTHER	9	4	4	1	2	10	11	3	44
	47.4%	16.7%	4.5%	.7%	16.7%	9.4%	4.2%	3.8%	5.9%

14. 12 UNITS(50.0%) STATED THAT AN APU WOULD INCREASE MAINTENANCE

15. 15 UNITS(62.5%) HAVE A BATTERY PROBLEM

16. AVERAGE NUMBER OF BATTERIES ISSUED PER UNIT LAST YEAR= 118.0

17. AVERAGE DAYS TACTICAL TRAINING LAST YEAR= 86.0

18. AVERAGE DAYS

A BATTALION 31.0

B COMPANY 31.0

C PLATOON 27.0

19. AVERAGE DAYS TANK GUNNERY TRAINING LAST YEAR= 52.0

FINISHED READING UNIT DATA. LINE 206

FINISHED INITIAL CALCULATIONS ON INDIVIDUAL DATA LINE 365

END SECOND PASS. LINE 540

APPENDIX D - DISTRIBUTION

APPENDIX D

DISTRIBUTION

VOLUME 1 - MAIN REPORT

DOD:

PM Mobile Electric Power - 1
Defense Documentation Center - 1

HQ DA:

DCSOPS - 2
DCSRDA - 2
DCSLOG - 1
ASDIRS - 1

HQ TRADOC:

ATCG - 1
ATCD - 1
ATCD-M - 4
ATTNG - 1
TRADOC Library - 1

TRADOC AGENCIES:

USACACDA - 2
USALOGCEN - 2
USA Admin Center - 2
USAADS (Combat Dev) - 2
USAAVNC (Combat Dev) - 2
USAES (Combat Dev) - 2
USAFAS (Combat Dev) - 2
USAIS (Combat Dev) - 2
USAOCS (Combat Dev) - 2
USASCS (Combat Dev) - 2
USATS (Combat Dev) - 2
TRASANA - 1
TCATA - 1
TSM XM-1/M60 - 2
TSM IFV/CFV - 2

COLLEGES & UNIVERSITIES

Comd & General Staff - 1
Armd Forces Staff - 1
Army War College - 1
ICAF - 1

DARCOM AGENCIES:

HQ DARCOM - 1
BSI - 1
TARADCOM - 4
ARADCOM - 1
HEL - 1
CORADCOM - 1
ERADCOM - 1
MERADCOM - 1
PM XM-1 - 4
PM M60 - 4
PM IFV/CFV - 1
TECOM - 1
CSL - 1

FORSCOM

HQ FORSCOM - 1
HQ, III Corps - 1
HQ XVIII Abn Corps - 1
1st Cav Div - 1
1st Inf Div (Mech) - 1
2d Armd Div - 1
4th Inf Div (Mech) - 1
5th Inf Div (Mech) - 1
7th Inf Div - 1
9th Inf Div - 1
24th Inf Div - 1
25th Inf Div - 1
82d Abn Div - 1
101st Abnl Div - 1
3d Armd Cav Regt - 1
6th Cav Bde - 1
172d Inf Bde - 1
193d Inf Bde - 1
194th Arm Bde - 1

USAREUR:

CINC USAREUR & 7th Army - 1
HQ, V Corps - 1
HQ, VII Corps - 1
1st Armd Div - 1
1st Inf Div (Mech) Fwd - 1
3d Armd Div - 1
3d Inf Div (Mech) - 1
5th Bde, 4th Inf Div (Mech) - 1
8th Inf Div - 1
2d Armd Cav Regt - 1
11th Armd Cav Regt - 1

KOREA

HQ, 8th Army - 1
HQ, I Corps - 1
2d Inf Div - 1

READINESS REGIONS

USARR I - 1
USARR II - 1
USARR III - 1
USARR IV - 1
USARR V - 1
USARR VI - 1
USARR VII - 1
USARR VIII - 1
USARR IX - 1

MARINE CORPS:

USMC Development and Education Center - 1

USAARMC & FT KNOX

CG - 1
DCG - 1
USAARMS - 10
DCD - 19
USAARMC LNO TO TCATA - 1
Ofc Armor Force Management - 2
USAARENBD - 4

VOLUME II - COMPUTER PROGRAM & SURVEY RESULTS

TARADCOM - 1
PM M60 - 1
PM XM-1 - 1
DOD PM Mobile Electric Power - 1
USAARMC
DCD - 16